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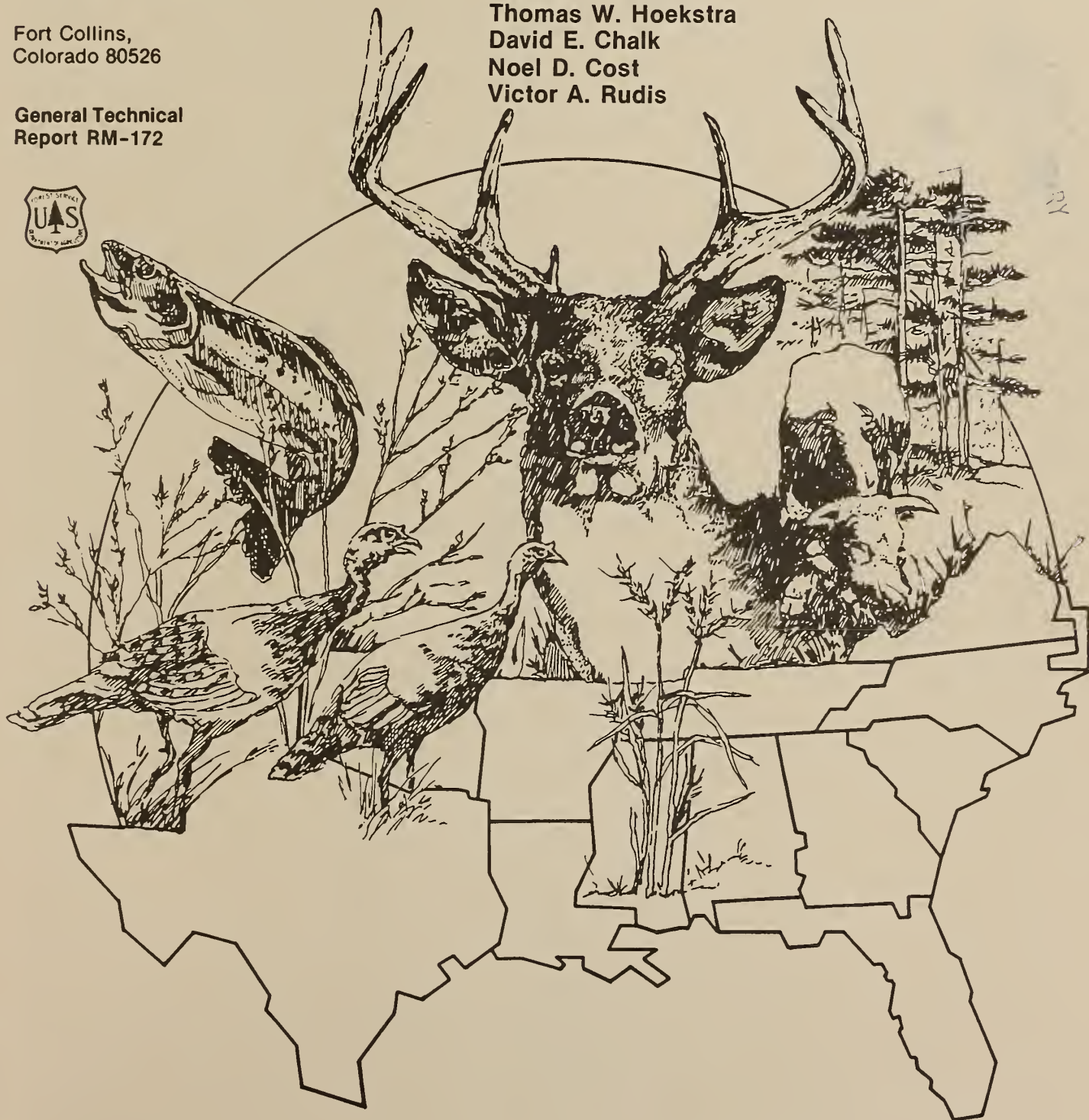
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# Recent Historical and Projected Regional Trends of White-Tailed Deer and Wild Turkey in the Southern United States

Curtis H. Flather  
Thomas W. Hoekstra  
David E. Chalk  
Noel D. Cost  
Victor A. Rudis



### **Abstract**

Large-scale resource assessments are required by the Forest and Rangeland Renewable Resources Planning Act of 1974. This report describes the wildlife component of a regional modeling framework used to analyze multiple resource response to land management. The modeling framework, as applied in the southern United States, links fish, forage, water, and wildlife resources to land use and timber models. White-tailed deer and wild turkey were selected for analysis and their recent historical status was reviewed. Habitat-based wildlife models were developed to analyze the impacts of land use and timber management. Discriminant function analysis was used to model the relationship between deer and turkey density classes with areal estimates of cropland, rangeland, urbanland, timber management types, and forest age classes within a county. Projected changes in the land base for a baseline and several alternative scenarios were applied to the wildlife models. Over a 50-year projection period, deer and turkey densities declined in response to increasing urbanization and conversion of natural forest types to pine plantations. This research has improved the capability to assess wildlife over large geographic areas and has demonstrated the feasibility of developing regional multiple resource analysis systems from existing land base inventories.

### **Acknowledgments**

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# **Recent Historical and Projected Regional Trends of White-Tailed Deer and Wild Turkey in the Southern United States**

**Curtis. H. Flather, Research Wildlife Biologist  
Rocky Mountain Forest and Range Experiment Station<sup>1</sup>**

**Thomas W. Hoekstra, Assistant Assessment Manager, RPA  
Rocky Mountain Forest and Range Experiment Station<sup>1</sup>**

**David E. Chalk, Wildlife Biologist  
Soil Conservation Service**

**Noel D. Cost, Resource Analyst  
Southeastern Forest Experiment Station**

**Victor A. Rudis, Research Forester  
Southern Forest Experiment Station**

<sup>1</sup>*Headquarters is in Fort Collins, in cooperation with Colorado State University.*

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## INTRODUCTION

Large-scale, multiresource analyses and planning are mandated by the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA).<sup>2</sup> This law requires the Forest Service to produce national descriptions of the current status and projections of future supply and demand for all renewable natural resources, including wildlife and fish.

Although identifying broad information needs, the law does not specify how national-level evaluations of natural resources are to be accomplished. Hoekstra and Hof (1985) identified three technical components that a national wildlife and fish assessment should address, including: (1) the recent historical trends in resource inventories (supply) and use (demand), (2) projections of resource inventories and uses, and (3) evaluations of opportunities to improve the future wildlife and fish resource situation. Components 2 and 3 require methodologies to project resource supplies and demands. In general, past wildlife and fish assessments (USDA Forest Service 1977, 1981) have only partially accomplished these tasks and, in many cases, have relied on resource specialists to speculate on future resource trends and management opportunities. Apart from a limited technical capability, past assessments also were criticized for not analyzing resources in the context of a multiple resource system; that is, the impacts or trade-offs of one resource on another were not addressed (Schweitzer et al. 1981). For wildlife resources, such evaluations require the capability to predict resource response to general land management activities.

A fundamental requirement of multiresource planning is to describe and monitor impacts of resource management on all resources, including wildlife. Modeling wildlife response to land management activities, however, is difficult (Hench et al. 1985). Techniques comparable with those being used for timber resources are generally not available (Crawford 1984). Consequently, there is a need to develop methods that will permit wildlife planning specialists to prescribe resource management based on impacts from likely future management alternatives.

One of the most insistent problems in meeting the legislative requirements implied by the RPA is developing objective, quantitative methodologies that are appropriate for national-level evaluations of wildlife and

<sup>2</sup>Public Law 93-378. *United States Statutes at Large*. Volume 88, p. 476 (P.L. No. 93-378, 88 Stat. 476).

fish. Although there have been recent efforts to develop objective models that relate wildlife species to habitat quality, the focus of these models has been to predict resource development impacts on wildlife habitat at a site-specific level (Hawkes et al. 1983). There is a need to recognize that informed resource planning decisions cannot be made exclusively at the site level (Risser et al. 1984). More emphasis is needed on analyses that explicitly address large geographic areas (Gall and Christian 1984, Sanderson et al. 1979).

This paper describes the wildlife component of a regional multiresource modeling framework that was developed to analyze multiple resource response to land management activities. The method discussed here improves the analytical basis for national wildlife assessments by developing regional supply projection models in a multiple resource context. The region (multiple states) was chosen as the geographic unit for analysis because environmental and economic attributes are more homogeneous within a region than at the national level (Joyce et al. 1986). The southern United States was the focus of a regional evaluation of the timber resource (USDA Forest Service 1988) and, therefore, served as an appropriate pilot test area for the regional multiple resource modeling framework proposed for national assessments of natural resources.

The objective of the wildlife modeling effort was to develop regional abundance models that were consistent and responsive to models that predicted regional shifts in land use (Alig 1984) and timber inventory characteristics (Tedder et al. 1987). This paper reports on the models developed for white-tailed deer (*Odocoileus virginianus*) and wild turkey (*Meleagris gallopavo*). Before discussing the wildlife modeling approach and application, we review the recent historical situation of wildlife resources in the South to provide a context within which to interpret the predicted future trends.

## CURRENT STATUS AND RECENT HISTORICAL TRENDS

### Current Resource Situation

The southern United States, from Texas to Virginia, supports one of the most diverse fauna in the country (table 1). The Southeast (Virginia, North Carolina, South Carolina, Georgia, Florida) and the South-central (Texas, Oklahoma, Arkansas, Louisiana, Mississippi, Kentucky,

Table 1.—Comparison of the number of resident and common migrant vertebrate species (and subspecies of special concern) in the United States. Figures in parentheses represent percent of national total. Percentages across regions will not sum to 100% since species can occur in more than one region.

	NE	NC	SE	SC	GP	RM	PC	AK
Amphibians	49(25)	57(29)	85(43)	102(57)	32(16)	34(17)	52(26)	6(3)
Birds	344(38)	328(36)	357(40)	488(54)	373(41)	458(51)	389(43)	217(24)
Fish	208(20)	262(25)	505(47)	382(36)	167(16)	199(19)	236(22)	53(5)
Mammals	81(20)	107(26)	99(24)	172(92)	107(26)	200(49)	218(53)	71(17)
Reptiles	48(14)	75(22)	105(30)	145(42)	71(20)	115(33)	76(22)	1(*)
Total	730(25)	829(28)	1,151(39)	1,289(44)	750(26)	1,006(34)	971(33)	353(12)

NE - Northeast, NC - North-central, SE - Southeast, SC - South-central, GP - Great Plains, RM - Rocky Mountains, PC - Pacific Coast, AK - Alaska.

\*Less than 1%.

Source: USDA Forest Service (1981).

Table 2.—Participation in wildlife-associated recreation by persons 16 years old and older for the nation and the South.

	Nation		South	
	Number (thousands)	Percent of U.S. population	Number (thousands)	Percent of regional population
Hunting	17,444	10.3	6,751	12.0
Big game	11,806	6.9	4,393	7.8
Small game	12,362	7.3	4,970	8.8
Migratory bird	5,311	3.1	2,505	4.4
Other	2,642	1.6	1,040	1.8
Nonconsumptive	93,249	54.9	25,780	45.7

Source: USDI Fish and Wildlife Service, and USDC Bureau of Census (1982).

Tennessee, Alabama) regions are ranked 1 and 2 out of 8 national regions measured in terms of the absolute number of vertebrate species.

The diverse fauna of the South attracts a large number and variety of recreational users. Nonconsumptive users numbered over 25 million, while hunting opportunities in the region drew 6.7 million users in 1980. Of these hunters, 65% hunted big game, 74% hunted small game, and 37% hunted migratory birds (table 2). Relative to the nation, the South supported higher participation rates in hunting [12.0 ( $\pm 0.2$ )% of the regional population compared to 10.3 ( $\pm 0.1$ )% nationwide]<sup>3</sup> while nonconsumptive participation [45.7 ( $\pm 1.0$ )% of the regional population]<sup>3</sup> was nearly 10 percentage points below the national rate.

The two most important game species in the South are the white-tailed deer and wild turkey (USDA Forest Service 1981). These species have been monitored and managed more intensively than most species in the region because of their importance to hunting. Consequently, the information base on deer and turkey populations, harvest, and use supported a detailed examination from both historical and future perspectives.

<sup>3</sup>Estimates of standard errors were calculated from formulas and tables presented in appendix C of USDI Fish and Wildlife Service, and USDC Bureau of Census (1982).

Currently, the South supports approximately 8.6 million deer and 1.4 million turkeys.<sup>4</sup> White-tailed deer are widely distributed across the South and inhabit a variety of habitats (Halls 1984). Populations reach their highest densities in the coastal plain region<sup>5</sup> where blocks of dense cover within forested areas of limited tree canopy cover are considered optimal deer habitat (Short 1986).

Wild turkey is a less widely distributed species than white-tailed deer. In the South, turkeys appear to prefer woodlands that are open and mature, comprised of mast-producing species, with scant ground cover and good eye-level visibility (Eichholz and Marchinton 1976, Lindzey 1967). The interspersed of forests with grassy open areas for brood rearing and nesting is also an important component in turkey habitat. Speake et al. (1975) recommended that spring/summer habitat in the Southeast should be 12–25% forest openings. The highest population densities are found in the bottomlands of the Mississippi, but densities are also high in the coastal plain of

<sup>4</sup>Unless otherwise cited, reported statistics on the population, harvest, and use of deer and turkey were obtained from state wildlife agencies.

<sup>5</sup>Southeastern Cooperative Wildlife Disease Study; turkey distribution map produced through Federal Aid in Wildlife Restoration Act, Contract No. 14–16–008–2024; deer distribution map produced through Cooperative Agreement No. 12–16–5–2230.

Alabama, the piedmont region of Georgia and South Carolina, and the mountains of Virginia.<sup>5</sup>

In 1983, the South's game species populations supported approximately 2.8 million deer hunters and 570,000 turkey hunters, who harvested 1.4 million deer and 195,000 turkeys. Of those hunters that pursued big game in the South, 95% hunted white-tailed deer or wild turkey (USDI Fish and Wildlife Service and USDC Bureau of Census 1982). These recreationists spent over \$11 million on hunting equipment, licenses, travel, and other related hunting expenditures (USDI Fish and Wildlife Service and USDC Bureau of Census 1982). State agencies depend on these expenditures (with the associated matching funds from federal programs) to manage their wildlife resources. Similarly, certain local economies depend on hunting-related expenditures, and the regional economy could be severely impacted if participation rates decline (Alward et al. 1984).

Although most big game are hunted on private lands, hunting on federal land is disproportionately high relative to the amount available. Federally administered lands comprise only 6% of the South's land base (USDA Forest Service 1981), yet 18.6% of the big game hunters used these public lands in pursuit of game (USDI Fish and Wildlife Service and USDC Bureau of Census 1982). The disproportionate use of federal lands cannot be completely accounted for by higher wildlife populations on these lands. National forests in 1980 supported 3.5% of the deer and 8.2% of the turkey populations in the South (USDA Forest Service 1982). Given that national forests comprise approximately 4% of the land base, the number of deer was slightly below, while turkeys were twice what was expected, assuming a distribution proportional to land area available. This illustrates the importance of public lands—particularly national forests which comprise 65% of the federal land in the South—in providing wildlife recreational opportunities in this region.

These estimates of population, harvest, and users present the status of the big game resource in the South for a single point in time. The magnitude of these numbers is difficult to interpret in terms of resource status without a historical review.

### Historical Resource Situation

Following European settlement of the North American continent, deer and turkey populations declined dramatically from exploitation caused by market and subsistence hunting, and habitat destruction caused by industrialization, timber harvesting, and conversion of forested lands to agricultural uses (Aldrich 1967, Halls 1978, McCabe and McCabe 1984, Miller and Holbrook 1983, Mosby and Handley 1943). Population levels of wild turkey had declined to such low levels that Fay (1884) predicted imminent extinction. By the turn of the century, an estimated 300,000 white-tailed deer (McCabe and McCabe 1984) and 30,000 wild turkey (Miller and Holbrook 1983) remained in the United States.

The recovery of whitetails and turkey, beginning around 1930, is frequently cited as one of the most

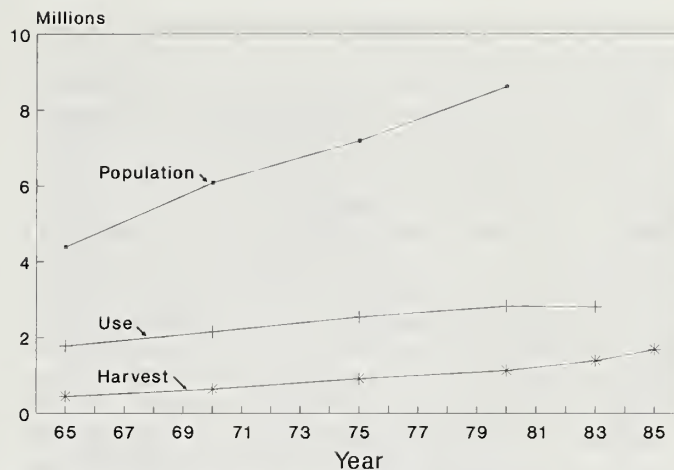


Figure 1.—Recent historical trends in deer population, harvest, and number of users for the southern United States.

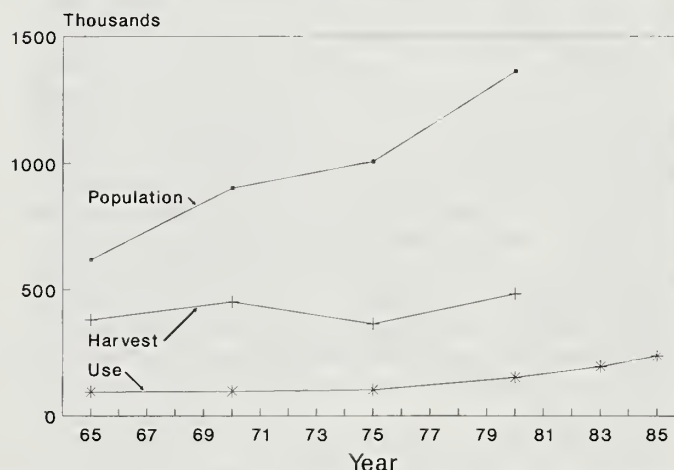


Figure 2.—Recent historical trends in turkey populations, harvest, and number of users for the southern United States.

significant accomplishments of modern wildlife management. The recovery was initiated by enforced protection, restocking programs, and habitat management. However, fortuitous land use changes greatly facilitated the observed increases in population. Regeneration of extensively clearcut forests, secondary succession on abandoned agricultural land, and migration of rural human populations to urban centers contributed greatly to the amount of suitable habitat available to the expanding populations (Barber 1984, McCabe and McCabe 1984, Miller and Holbrook 1983).

In more recent times, deer and turkey populations have continued to increase. Between 1965 and 1980, deer populations increased 96% from 4.4 to 8.6 million animals, for an average annual increase of approximately 282,000 deer (fig. 1). Harvest levels and number of deer hunters have increased as well, but at a slower rate. Over the same period, harvest levels increased 45,000 per year, while the number of hunters increased at an average annual rate of 70,000 (fig. 1).

Trends in wild turkey are qualitatively similar to deer trends (fig. 2). Turkey populations increased by 120% from 1965 to 1980, for an average annual rate of 50,000 birds. Harvests levels have increased 4,000 per year and

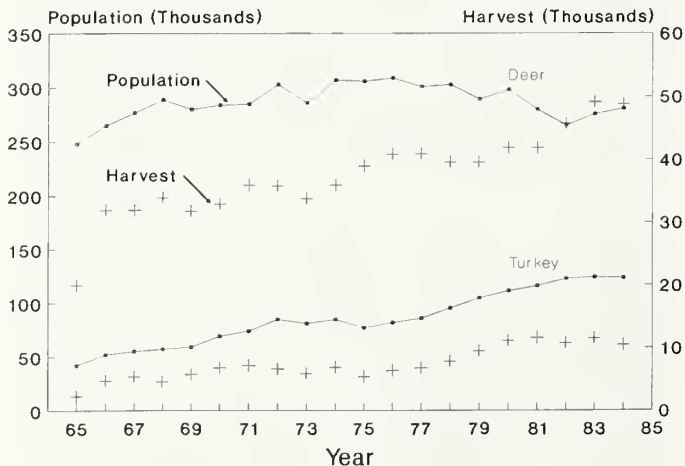
the number of turkey hunters increased 7,000 per year over the same period.

Deer and turkey population trends on national forests in the South do not show the significant gains reported across all ownerships (fig. 3). Deer populations remained fairly stable around 280,000 animals from 1965 through 1984. Conversely, turkey populations have increased steadily since 1965. Introduction of birds into previously unoccupied habitat has resulted in an average annual increase of approximately 4,000 birds. Although deer populations have remained stable, harvest of deer from national forests has more than doubled from 20,000 to 49,000 animals. Similarly, turkey harvest increased from 2,300 birds in 1965 to 10,400 birds in 1984.

Although the recent trends in deer and turkey populations, harvest, and users suggest a secure future for these resources in the South, there is evidence to suggest that increased expenditures for management will be required to maintain deer and turkey populations, and the quality of big game hunting (Bailey 1980, Halls 1984, Miller and Holbrook 1983). Increasing human populations mean increased demands for multiple products and uses from a finite land base. Consequently, there is a high potential for increased resource conflicts that will necessitate careful planning to ensure that multiple resource demands can continue to be supported across the region. To address multiple resource planning for wildlife resources, a modeling framework was developed to permit an assessment of wildlife response to land use and timber management changes. This framework represents the first time that wildlife models have been linked to changes in land use and timber management at a regional scale.

## MODELING APPROACH

Wildlife habitat can be defined as the availability and interspersed of food, cover, and water. Habitat represents a spatial concept characterized by a particular com-



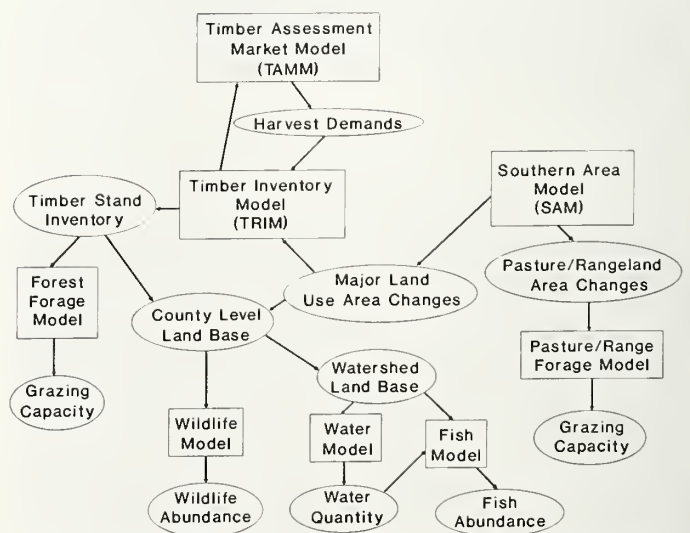
**Figure 3.—Recent historical population and harvest trends for deer and turkey on National Forest System lands in the South (source: USDA Forest Service 1965–1977, 1978–1984).**

bination of physical and biotic factors within a defined geographic area that determines whether an animal can survive and reproduce (Partridge 1978). The description of a species habitat is dependent on the scale of the resource management problem (Flather and Hoekstra 1985). At the regional scale, patterns in land use and forestland characteristics (e.g., forest type and age class) define a coarse representation of wildlife habitat appropriate for this level of analysis (Joyce et al. 1986, Klopatek and Kitchings 1985). Like wildlife habitat, other resources such as forage, fish, and water are also affected by the particular pattern of land use and land cover. It is this dependence on land base characteristics, made explicit through common definitions of land use and land cover types, that served as the basis for developing the multiple resource analysis framework, of which wildlife is one component.

## The Multiresource Framework

A major obstacle in the development of multiple resource analyses has been the definition of a conceptual basis for linking resources. Joyce et al. (1986) proposed an analysis framework for integrating regional resource models for use in large-scale assessments of natural resources. The framework (fig. 4) links forage, wildlife, fish, and water resource models to three models that project changes in the land base.

Acreage projections in various land uses including cropland, pasture and rangeland, human land uses (urban, roads, farm structures, etc.), and timber management types (natural pine, planted pine, oak-pine, upland hardwood, lowland hardwood) were provided for each state by the Southeastern Area Model (SAM) (Alig 1984). Stand characteristics within each timber type were further described by the Timber Resource Inventory Model



**Figure 4.—Multiple resource model framework for linking individual resource models at the regional level. Boxes are models and ellipses are databases or model outputs. Arrows represent information transfers among resource models. (after Joyce et al. 1986).**

(TRIM) (Tedder 1983, Tedder et al. 1987). The timber inventory model interacts with the Timber Assessment Market Model (TAMM) (Adams and Haynes 1980) to equilibrate supply (TRIM) and demand (TAMM) of forest products. The output from this equilibrating process is a subregional (Southeast and South-central) projection of the growing stock volume and land area estimates by ownership, timber type, site class, and age class categories.

To link the wildlife and other resource models to the land base projection, all models were required to operate from a commonly defined set of land use and forest cover descriptors. Linkage through a common land base classification was less constraining than requiring all resources to operate at a common geographic unit. Use of a commonly defined land base permitted the choice of the geographic unit deemed appropriate for each resource. An important geographic consideration in the wildlife analysis was species motility. Motility can either be modeled explicitly through the specification of dispersal functions or by analyzing geographic areas of sufficient size that motility is not a significant process. The latter approach was used to relate wildlife populations to spatially stationary habitat characteristics. The county was chosen as the geographic unit to establish the relationships between land use pattern and wildlife densities.

Currently, the potential influence of forage, wildlife, fish, and water resources on timber management and the economics behind land use changes and land management decisions has not been incorporated into the multi-resource framework. The analysis system, at this stage of development, has been designed only to evaluate the impacts of land use shifts and timber management on other resources.

### Wildlife Habitat Models

Prediction models for wildlife can be categorized into two broad classes: population parameter models and habitat-based models. Prediction of wildlife populations based on estimates of population structure, natality, and mortality rates is difficult, and few techniques are applicable to regional and national analyses (Hawkes et al. 1983). In addition, wildlife impacts cannot be evaluated unless the functional relationships between population parameters and land management actions are known.

An alternative means of modeling wildlife resources is through habitat-based approaches. The occurrence and abundance of wildlife species are generally recognized to be influenced by the relationship of a species to its habitat. Although the influence of interspecific interactions and other nonhabitat factors on animal populations is recognized (Flather and Hoekstra 1985), information that permits consideration of such factors is limited and, therefore, rarely incorporated into analytical models.

Habitat-based models have several characteristics that make them conducive to large-scale analyses of shifting patterns in land use and land cover. First, habitat is easily inventoried relative to inventories of wildlife popula-

tions, and several databases support regional descriptions of land use and land cover. Second, habitat-based models establish a direct link between wildlife populations and the entity altered by land management activities: their habitat.

Habitat-based models provide measures of habitat suitability or some estimate of population level or density. Habitat suitability models are the most common and tend to be based on expert knowledge of a species' natural history. Models developed by the USDI Fish and Wildlife Service (1980) (HEP), Boyce (1977) (DYNAST), and the U.S. Army Corp of Engineers (1980) (HES) are typical examples of this approach. However, it has been difficult to establish verifiable relationships between habitat suitability and observed wildlife numbers (Cole and Smith 1983, Lancia et al. 1982).

Less commonly, some habitat-based models predict population levels or abundance classes directly from characteristics of the habitat. Outputs expressed in animal numbers are necessary to understand wildlife use implications and opportunities, since animals are the resource used and perceived by people; habitats are difficult to interpret in those respects. The habitat-population relationships tend to be empirically derived rather than mechanistic, functional relationships. For example, Williams et al. (1977) developed a method based on pattern recognition principles that predicts an expected long-term population level for a particular area. A more rigorous extension of pattern recognition principles entails the use of multivariate statistical techniques. Multivariate procedures are acknowledged as a suite of methods that inherently fit habitat evaluation problems (Shugart 1981).

Although habitat-based population analysis techniques are available, most have been developed and applied at the site-specific level. Geographic aggregation of results from site-specific models is impractical and inappropriate to produce regional-scale summaries for national assessments (Hawkes et al. 1983). Similarly, arbitrary application of a site-level model to a region as a whole is not recommended (Risser et al. 1984). Consequently, development of new wildlife models with inventory data consistent with the intended scale of application was required.

### REGIONAL DEER AND TURKEY MODELS

The objective of the wildlife models was to develop a regional-level projection tool that could be used to assess potential impacts from land use shifts and forest management. Based on the geographic scale of interest and the constraint that there were no known functional relationships between wildlife and land base patterns at the regional scale, an empirical approach using multivariate statistical analyses was chosen. The approach, similar to that of Klopatek and Kitchings (1985), uses discriminant function analysis to establish the statistical relationships between land use and forest vegetation descriptors and relative abundance classes of white-tailed deer and wild turkey at the county level.

## Land Area Database

County land area estimates by land use and land cover categories were obtained from the Soil Conservation Service (SCS) National Resource Inventory (NRI) (USDA Soil Conservation Service and Iowa State University Statistical Laboratory 1987) and the Forest Service (FS) Forest Inventory and Analysis (FIA) (USDA Forest Service 1985) regional surveys. Estimates of total county land and water area were obtained from the Bureau of Census (USDC Bureau of Census 1970). The FIA survey was used to obtain area estimates of commercial forestland for timber management types (natural pine, planted pine,

oak-pine, upland hardwood, and lowland hardwood) and forest age class. The NRI was used to obtain estimates of all other land types (crop-, pasture-, range-, and urban-land uses). Combining FS and SCS inventories to characterize total county land area resulted in discrepancies when compared to Bureau of Census estimates of total county area. This discrepancy resulted because the two inventories are not mutually exclusive. Iterative proportional fitting (Deming and Stephan 1940) was used to adjust FS and SCS inventory data to more closely approximate the total county land area reported by the Bureau of Census.

The predictor variables used in the development of the wildlife models are defined in table 3. All land area

Table 3.—Definition of land use and land cover variables used to develop wildlife models.

Variable acronym	Variable definition
TOTCRP	total cropland acreages including estimates of row crops, close grown crops, horticultural crops, unplanted cropland, and other cropland
TOTPAST	total pastureland and rangeland acreages including estimates of pasture, range, and rotation hay and pasture
HUMAN	total acreages associated with human development including estimates of urbanland, roads, railroads, strip mines, and farm structures
NP	total acreage estimates of natural pine acreage estimates of natural pine by age class
NPA1	age class 1: 0 – 20 years
NPA2	age class 2: 21 – 50 years
NPA3	age class 3: 50+ years
PP	total acreage estimates of planted pine acreage estimates of planted pine by age class
PPA1	age class 1: 0 – 10 years
PPA2	age class 2: 11 – 30 years
PPA3	age class 3: 30+ years
OP	total acreage estimates of oak-pine acreage estimates of oak-pine by age class
OPA1	age class 1: 0 – 20 years
OPA2	age class 2: 21 – 50 years
OPA3	age class 3: 50+ years
UH	total acreage estimates of upland hardwood acreage estimates of upland hardwood by age class
UHA1	age class 1: 0 – 20 years
UHA2	age class 2: 21 – 50 years
UHA3	age class 3: 50+ years
LH	total acreage estimates of lowland hardwood acreage estimates of lowland hardwood by age class
LHA1	age class 1: 0 – 20 years
LHA2	age class 2: 21 – 50 years
LHA3	age class 3: 50+ years
AGE1	acreage estimates for age class 1 across all forest types (except PP)
AGE2	acreage estimates for age class 2 across all forest types (except PP)
AGE3	acreage estimates for age class 3 across all forest types (except PP)
HWAGE1	acreage estimates for age class 1 across hardwood types (OP, UH, LH)
HWAGE2	acreage estimates for age class 2 across hardwood types (OP, UH, LH)
HWAGE3	acreage estimates for age class 3 across hardwood types (OP, UH, LH)

variables are expressed as a proportion of a given county. Information on the size, shape, and distribution of the land area components was not available.

### Wildlife Database

Abundance data for white-tailed deer and wild turkey were obtained from the Southeastern Cooperative Wildlife Disease Study, University of Georgia.<sup>5</sup> Maps depicting distribution and abundance of turkeys in 1980 and white-tailed deer in 1982 were used to categorize each county into one of three density classes: low, moderate, or high. Although a categorical wildlife response variable results in a coarse description of population-habitat relationships, such as an approach was deemed more appropriate than modeling actual population numbers, given the magnitude of potential error associated with region-wide population estimates and past difficulties associated with relating actual numbers to measures of habitat quality (Cole and Smith 1983, Lancia et al. 1982). Counties were assigned to density classes by taking an area weighted mean of mapped density classes within each county. Areas were estimated by planimetry density class boundaries within each county. A frequency distribution of the weighted mean densities was examined for natural breaks, which were used to define the density value cutpoints for high, moderate, and low density classes. The average midpoint density levels for all strata were as follows:

	White-tailed deer	Wild turkey
Low	9/sq. mile	3/sq. mile
Moderate	19/sq. mile	7.5/sq. mile
High	29/sq. mile	14/sq. mile

Computer-generated maps of these data were reviewed by state wildlife agencies. A total of 772 counties were used to develop the deer models, and 766 counties were used to develop the turkey models.

### Model Development

Discriminant function analysis (Johnson and Wichern 1982) was used to develop the statistical relationships between land use and land cover descriptors, and density classes for deer and turkey. Our objective in using discriminant analysis was to generate classification rules that could be used to predict density class membership (low, moderate, or high) based on land base predictor variables. Counties served as the observational unit and, therefore, the set of objects to be classified. Model adequacy was based on classification accuracy as measured by the percentage of counties in the sample that were correctly classified by the sample classification functions. Separate models for six physiographic strata (mountain, piedmont, eastern coastal plain, mid-south coastal plain, Mississippi Valley, and western coastal plain and highlands) were developed for both deer and turkey (fig. 5). The stratification was based on the SCS Major Land Resource Area (USDA Soil Conservation

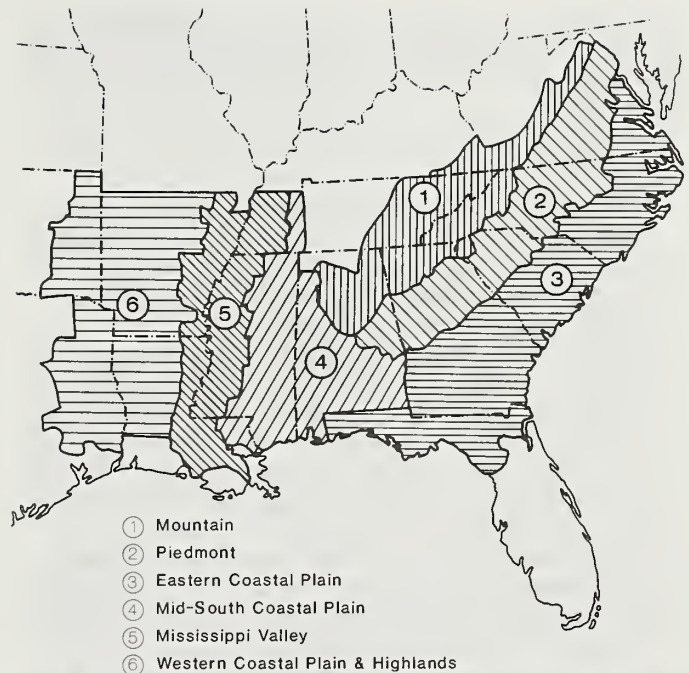


Figure 5.—Land base stratification for white-tailed deer and wild turkey models.

Service 1981). The models do not include peninsular Florida or the gulf coast counties of Texas and Louisiana because the small number of counties in these unique land types did not permit development of multivariate models. All calculations were performed using the Statistical Analysis System (SAS 1985a, 1985b).

Two assumptions critical to discriminant analysis are that the predictor variables be distributed multivariate normally within each classification group and the covariance structure between classification groups be similar (i.e., homogeneity of covariance) (Johnson and Wichern 1982). The assumption of multivariate normality is difficult to test directly. In practice, one has to be satisfied with subjecting each variable to univariate tests of normality (Habbema and Hermans 1977). Because all independent variables represented proportions, the normality assumption was violated by definition. All variables were transformed ( $\arcsin[\sqrt{x}]$ ) prior to statistical analysis to more closely approximate a normal distribution. The UNIVARIATE procedure (SAS 1985b) was used to test each variable for univariate normality (Shapiro-Wilk statistic for  $n < 50$ ; Kolomogorov statistic for  $n > 50$ ). Testing for homogeneity of covariance resulted in rejection of this assumption in all cases—a common characteristic of ecological data (Williams 1983). Failure to meet this assumption resulted in the generation of classification rules based on quadratic discriminant functions rather than linear functions. Consequently, discrimination between classes is not based on means alone but considers differences in variances as well (Johnson 1981).

Selection of model variables was based on several criteria. Significant deviations from univariate normality resulted in elimination of variables from further consideration. In most cases, this resulted in the elimination of land base variables that were rare within a particular

physiographic stratum and, therefore, less likely to be of ecological significance in explaining distribution and abundance of a species within that physiographic stratum.

This initial subset of predictor variables was further reduced in three steps:

1. Examination of correlations among predictor variables resulting in the elimination of one of a pair of highly correlated variables. That variable presumed to be of greater ecological significance was chosen to remain in the model.
2. Insignificant ( $p > 0.10$ ) results from univariate analysis of variance were used to flag variables for potential removal. Variables with insignificant ANOVA results were not automatically eliminated, however, because failure to establish univariate relationships does not preclude explanatory power under multivariate analysis.
3. Variables flagged in step 2 were then sequentially removed, and model performance (classification accuracy) was used to determine whether the variable was eliminated from the model.

This approach to variable selection was an attempt to maximize the classification accuracy of the model with the least number of predictor variables. Stepwise procedures were not used because of noted problems when the number of classification groups is larger than two—namely that the F-criterion emphasizes selecting variables associated with the best separated pair of classification groups, which can result in larger error rates (Habbema and Hermans 1977). The variable selection procedure included five to eight variables in the deer models (appendix A) and four to eight variables in the turkey models (appendix B). Tests for group differences based on the MANOVA results showed significant group differences ( $p < 0.01$ , Wilk's lambda).

A technical review committee comprised of three biologists from the South with knowledge of the species being modeled was assembled to evaluate model specification and performance. White-tailed deer and wild turkey habitat relationships established during model development were consistent with the review committee's expectation. White-tailed deer densities were negatively related to increased area of human-related land use. Cropland had a negative influence on deer density in areas dominated by agricultural land use (Mississippi Valley, western coastal plain and highlands). Cropland had a positive influence on deer density in the mountain stratum where forest cover dominated, presumably because of increased forestland/cropland edge habitat. Higher deer densities were also associated with early forest successional stages represented by young forest age classes.

Wild turkey densities were negatively associated with increased area in cropland and human-related land uses. Increased area in natural forest types, in particular upland and lowland hardwoods, and older age classes of hardwood types, were associated with higher turkey densities.

Model classification success rates for white-tailed deer and wild turkey averaged 79% and 82% region-wide. Classification success across strata ranged from 73% to 85% for white-tailed deer and 75% to 87% for wild turkey. Factoring out correct classifications attributable to chance showed that, across strata, the deer models performed 57% to 76% better than a random model, while the turkey models outperformed a random classifier by 61% to 72%. In all cases, the number of counties correctly classified was significantly better than a random model ( $p < 0.001$ , Kappa statistic) (Cohen 1968, Titus et al. 1984).

Although these classification accuracies indicate an overall good relationship to the data, accuracy measures based on data used to generate the models are likely to be optimistic. Jackknife estimation has been proposed as a less biased estimate of classification accuracy (Efron and Gong 1983, Johnson and Wichern 1982). The approach involves: holding one observation out; generating classification functions on the remaining observations; classify the "held-out" observation; repeat until each observation has been held out. Jackknifed estimates of region-wide model classification accuracy for white-tailed deer and wild turkey were 60% and 67%, respectively. Across strata, jackknifed estimates of accuracy ranged from 53% to 67% for deer and 60% to 77% for turkey.

## MODEL APPLICATION

The models generated by the discriminant analysis were used to classify "new" counties; that is, counties where group membership was not known with certainty. "New" counties can be created by hypothetical or predicted changes in land use and land cover over the entire South.

In our application, shifts in the land base variables were predicted by the three land base area projection models in figure 4. Acreage projections of major land use categories (timber management type, cropland, pastureland/rangeland, urbanland) were made by econometrically based land area regression models (SAM) (Alig 1984). Regional changes associated with forest age class acreages were provided by TRIM (Tedder 1983, Tedder et al. 1987) and TAMM (Adams and Haynes 1980). In addition, SAM and TRIM described the forestland base by four ownership classes (national forest, other public, forest industry, and other private). Ownership categories permitted a more accurate representation of the land base by tracking ownership differences in timber management. Land bases were projected for the years 1985, 1990, 2000, 2010, and 2030.

The coupling of these models requires that wildlife model variables be consistent with the outputs provided by the inventory projection models. Although land base definitions are consistent, the models operated at different scales: TRIM provided forest age characteristics at the subregional level (Southeast and South-central), while SAM provided information at the state level. Since the wildlife models require county level information, the

projected changes in land area were used to adjust initial county level estimates of land use and land cover. This adjustment was accomplished through the iterative proportional fitting procedure described earlier and simulation of timber growth and harvest.

Wildlife responses to projected changes in land use and land cover patterns were assessed by calculating a region-wide weighted average density level for deer and turkey. Application of the discriminant function models produces a probability estimate of membership in each of the three density classes for each county. Averaged over all counties, these probabilities represent a regional probability for each density class. The regional probabilities calculated in this way provided the weights that were applied to the density level associated with each of the three density classes as follows:

$$D = p_l d_l + p_m d_m + p_h d_h$$

where D is the overall average density for the region, p is the mean posterior probability of membership in abundance class l (Low), m (Moderate), or h (High), and d is the midpoint density level associated with each abundance class.

For the application reported here, it was important to maintain a subregional level of geographic resolution. As described earlier, the two subregions in the South are the Southeast (Florida, Georgia, North Carolina, South Carolina, and Virginia) and the South-central (Alabama, Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas). These subregions correspond to the geographic aggregations reported by TRIM and were important to the timber resource policy analysis being completed for the Southern forests (USDA Forest Service 1988). For this reason, the projected deer and turkey trends are discussed individually for both the Southeast and South-central subregions. Before discussing the application results, a review of model assumptions will provide a reference point for interpretation.

### Ecological Assumptions

A number of assumptions were required to model the possible impacts of changing land use and forest vegetation characteristics on wildlife abundance. These assumptions acknowledge factors that influence wildlife numbers that currently could not be incorporated into the model. These assumptions form the context within which findings from the model can be interpreted, for they specify the limitations of current available information. Incorporation of these assumptions into regional models of wildlife abundance will require further research. The specific ecological assumptions made in this analysis were as follows:

1. Wildlife density estimates used in building the habitat relationship models were at the carrying capacity of the habitat. The regional habitat-based population models assume that similar patterns of land use and forest vegetation will support similar densities of deer and turkey. This is possible only if the observed density levels associated with each

county are at or near the capacity of the habitat.

2. Wildlife population changes predicted over the projection period are due solely to changes in land use and forestland characteristics. Nonhabitat factors that influence deer and turkey density are assumed to remain constant across counties and over the projection period. For example, interspecific competition and predation rates are assumed constant. Similarly, factors that affect animal density attributable to wildlife management (such as harvest regulations, transplant programs) are assumed to continue in the future at a level practiced in the recent past. The relationship between harvest pressure and incidence of vehicle-kills, and human-related land use is assumed not to change across the region or over time.
3. Timber management activities will continue about as in the recent past and, therefore, will not effectively change wildlife population responses over the projection period. For example, management of pine plantations is assumed not to change in a way that will benefit wildlife (e.g., alter spacing of trees to make understory characteristics more favorable to certain wildlife species).
4. Patterns of landscapes (the size, shape, and distribution of land uses) will not change dramatically over the projection period. For example, there will not be a significant shift to large, consolidated cropland areas or significant increases in forestland fragmentation.
5. It was assumed that the average density level of deer and turkey for each time period was a function of land base characteristics and the proportion of counties predicted in each density class for the previous time period. Consequently, if the models predict an increase in the number of counties from one time period to the next, then the model will recognize an increased chance of classifying counties into the high density category in the next projection period.

We recognize that these are simplifying assumptions, but the data were not available to incorporate their influence in the habitat-population relationships or in projecting how they change over time. In addition, it should be emphasized again that the wildlife modeling effort represents an impact analysis that is entirely dependent upon the land use and timber inventory projections. Feedback mechanisms whereby the wildlife responses alter the timber resource and timber management, as well as explicit incorporation of the assumptions made here, are being considered for future research in regional wildlife habitat models.

### Baseline Scenario

Possible impacts on wildlife resources resulting from land management activities were evaluated by running land area and timber inventory models assuming a likely future trend in land use and timber management. The assumptions made in the baseline analysis were devel-

oped from expert opinion on what the likely demand for timber products will be and what level of timber management would be required to ensure that timber supplies would meet that demand (USDA Forest Service 1988). This particular parameterization of the land base models provided a baseline condition for comparisons against alternative future scenarios.

Projected land area changes for the Southeast and South-central subregions between 1985 and 2030 are summarized in table 4. The projected trends indicate more intensive forest management and more human-dominated land uses. Forestland area in general, and to a lesser degree pastureland, decline over the projection period. Cropland shows slight gains, particularly in the South-central subregion. Human-related land uses show relatively large increases across both subregions. The most notable forest type changes projected were conversion of natural forest types to pine plantations. Natural pine accounts for the majority of the converted acres, but oak-pine and upland hardwood types also will be harvested and planted to pine. The major changes in forest stand structure involve gains in younger forest age classes in both subregions and increases in older age classes in the South-central.

White-tailed deer, a generalist in its habitat requirements, was predictably not explicit in its response to changes in any single land cover characteristic. The deer models project a density decline in both the Southeast and South-central for an average regional decline that approaches 20% (fig. 6). The decline was attributed to an overall loss of forest habitat, specifically upland hardwoods, and the conversion of natural pine and oak-pine stands to planted pine. Increased acreages in human-related uses, including urbanland and roads, also contributed to the overall decline in deer numbers. These uses directly reduce available habitat and are associated with increased mortality from associated disturbances (e.g., vehicle kills, hunting pressure).

Wild turkey have more specific habitat requirements than deer and are closely tied to the hardwood component of the forestland base. Increased human-related land

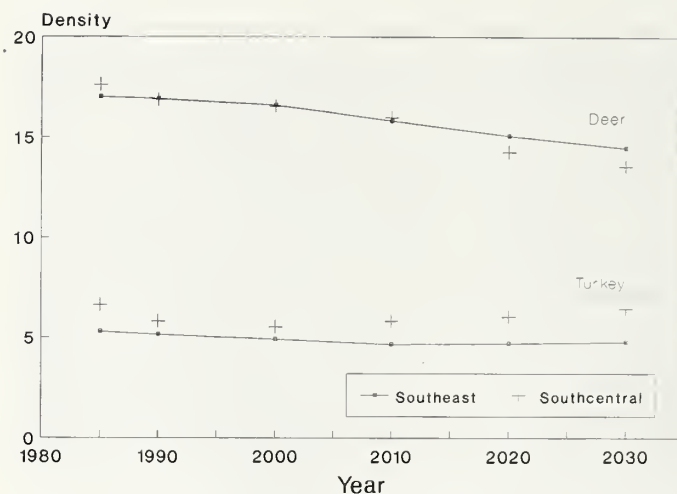


Figure 6.—Projected changes in white-tailed deer and wild turkey density (no./sq. mile) for the Southeast and South-central subregions.

use and the general loss of upland hardwood and oak-pine types contribute to the initial decline in the projection (fig. 6). After the year 2000, however, average turkey density levels off in the Southeast and recovers in the South-central in response to increased acres in older hardwood stands.

The greater decline in deer compared to turkey is likely a function of the distribution of density classes relative to private and federal land ownership. National forests constitute the majority of the federal lands across the South, with 24% of the counties containing some national forest land. Consequently, management on private land can have a significant impact on deer and turkey populations. Within those counties lacking national forest land, 56% support moderate to high deer densities, while only 37% support moderate to high turkey densities. Within counties containing national forest land, 27% support high turkey densities, while 14% support high deer densities. This pattern suggests that the projected intensification of land use and timber management on private lands can have a more negative impact on deer than turkey populations.

### Alternative Scenarios

Fourteen alternative scenarios were defined in the timber resource policy analysis for the southern forests (USDA Forest Service 1988). The wildlife models were able to analyze potential impacts for the five alternatives that would change the commonly defined land base (see appendix C for a description of scenarios):

7. Increased Stumpage Costs
8. Reduced Timberland Area
9. Reduced Timber Growth
10. Reduced National Forest System Harvest
13. Economic Opportunities on Private Timberlands

Projections of deer and turkey density under each alternative show little deviation from the baseline condition. For both deer and turkey, the change in density over time is greater than the change between alternatives and the

Table 4.—Projected land area changes (percent of total land base) in the South between 1985 and 2030.

	Southeast		South-central	
	1985	2030	1985	2030
TOTCRP	14.8	15.0	18.3	19.5
TOTPAST	12.9	12.1	17.9	15.4
HUMAN	8.9	12.5	6.0	10.0
TOTAL FORESTLAND	57.8	54.7	55.0	52.1
NP	14.4	7.2	11.0	6.1
PP	8.5	14.8	5.0	12.4
OP	6.6	6.7	9.7	6.6
UH	18.9	17.9	9.5	9.1
LH	9.2	8.1	9.5	9.1
AGE1	10.3	16.3	16.4	18.7
AGE2	23.8	13.0	31.1	11.3
AGE3	15.1	10.7	2.4	9.7
HWAGE1	6.6	12.7	12.2	15.1
HWAGE2	14.7	9.7	24.6	8.9
HWAGE3	13.5	10.3	2.1	9.7

baseline (appendix D). This is due, in part, to: (1) the alternatives were developed to test impacts on timber resources rather than to test land type changes that could be significant to deer and turkey distribution and abundance, and (2) the relatively small changes in the projected land base in the five scenarios analyzed. Scenarios 8 (Reduced Timberland) and 13 (Economic Opportunities on Private Timberlands) were the only alternatives that resulted in any change in land use or timber management types relative to the baseline. The remaining three scenarios only affected forest age class distributions.

To facilitate comparisons among scenarios, the wildlife responses and land base changes have been indexed. The index uses the 1985 wildlife density or land type proportion as the base and divides each subsequent projection period by the base. Consequently, the index should be interpreted as the change relative to 1985. Because of the limited variation in wildlife response across scenarios, only those scenarios that resulted in perceptible differences from the baseline will be discussed.

### White-Tailed Deer Response to Alternatives

In the Southeast, the Reduced Timberland (8) scenario resulted in the greatest deviation in deer density from

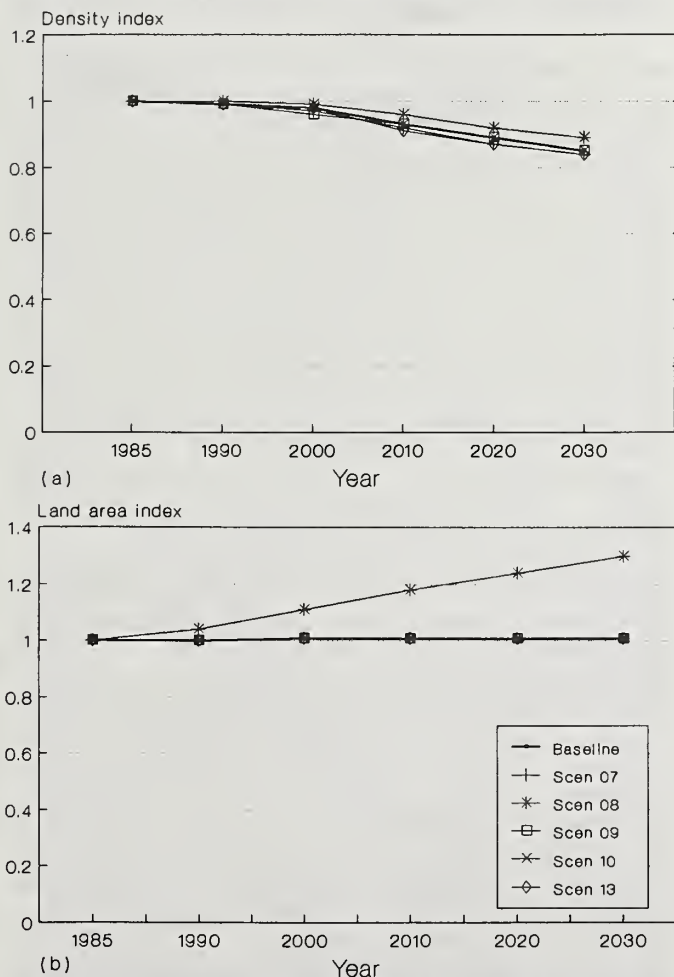


Figure 7.—Comparison of (a) indexed deer density response, and (b) indexed total cropland area change between the baseline and alternative land base scenarios in the Southeast subregion.

the baseline condition (fig. 7a). Deer decline less rapidly than in the baseline due to increased land type diversity associated with conversion of timberland to cropland. The loss in timberland acreages is distributed across all timber management types and age classes, resulting in small differences in type and age class patterns from the baseline. Human-related land uses and pastureland are unchanged from the baseline condition. Cropland is projected to increase from 14.9% to 19.3% of the total land base (fig. 7b). The Southeast is dominated by timberland cover, particularly in the mountain and, to a lesser degree, in the piedmont regions. Although information on the size, shape, and distribution of land use is not explicitly included in the deer models, the presumed fragmentation of the forestland base associated with this alternative would result in more favorable edge habitat conditions.

In the South-central subregion, deer density declines noted under the baseline were moderated under the Increased Stumpage Costs (7) and Economic Opportunities on Private Timberland (13) scenarios (fig. 8a). Land use changes (cropland, pastureland, rangeland, and human-related land uses) are unaltered from the baseline conditions. Deer density appears to be responding to

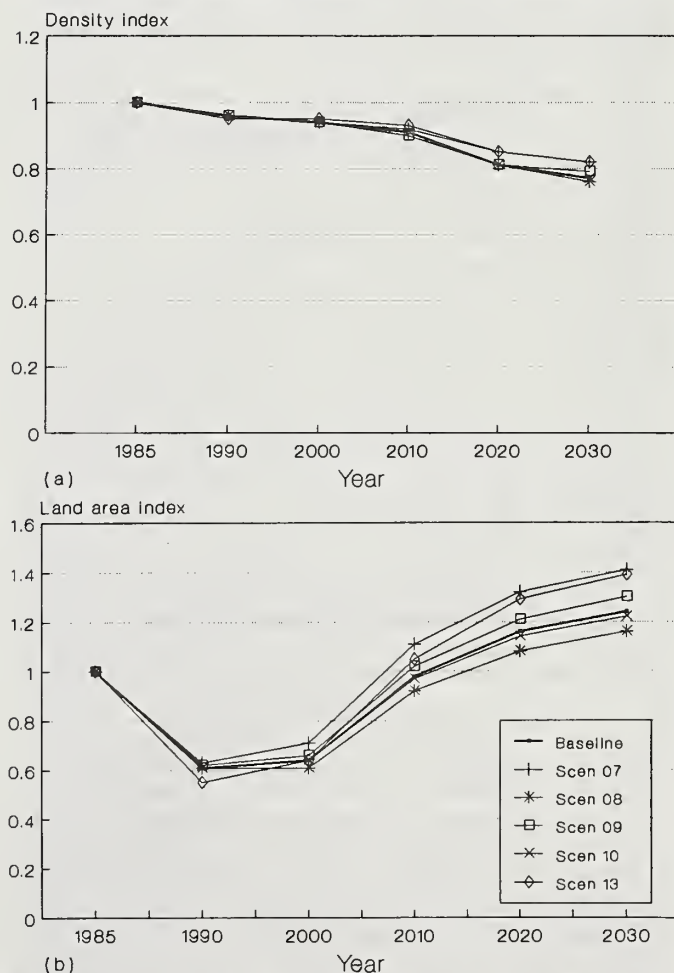


Figure 8.—Comparison of (a) indexed deer density, and (b) indexed younger hardwood (age class 1) area change between the baseline and alternative land base scenarios in the South-central subregion.

increased acreages associated with early forest successional stages as represented by younger-aged stands, particularly hardwood types. The South-central is currently dominated by medium-aged forest stands. As these stands move into the harvestable age classes, large increases in younger-aged stands as cutover acres are regenerated can be expected. Scenarios 7 and 13 resulted in the greatest increases in area of younger hardwood types (fig. 8b).

### Wild Turkey Response to Alternatives

Wild turkey densities are, in general, less responsive to the alternative scenarios than are white-tailed deer. In the Southeast, wild turkey densities deviated only slightly from the baseline under the Reduced Timberland (8) and Economic Opportunities on Private Timberland (13) scenarios (fig. 9a). Under the Reduced Timberland alternative, turkey densities are projected to decline slightly more than under the baseline. The increased acres in cropland (fig. 7b) and the reduction in hardwoods, such as bottomland types (fig. 9b), contribute to this decline. The density decline is moderated slightly under an alternative of greater economic opportunities

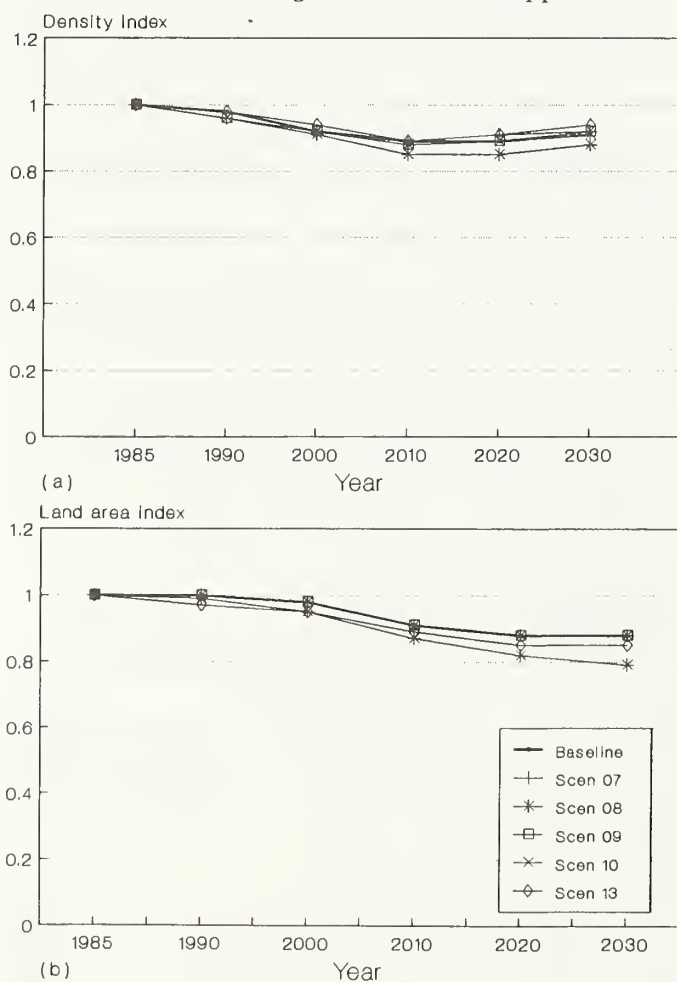


Figure 9.—Comparison of (a) indexed turkey density response, and (b) indexed area change for lowland hardwoods between the baseline and alternative land base scenarios in the Southeast subregion.

for timber on private lands. The land base changes under this alternative are similar to the Reduced Timberland (8) scenario with these noted exceptions: (1) natural forest types are converted to pine plantations rather than cropland, (2) natural pine and oak-pine stands contribute more to the lost acreages of forest types than do the hardwood types, and (3) there is a gain in younger hardwood stands which, in the early years of this age class, can provide grassy open areas used as nesting and brood-rearing habitat in a region already dominated by older-aged hardwoods.

South-central turkey densities were most responsive to the land base projection under the Economic Opportunities on Private Timberland (13) scenario (fig. 10a). The observed turkey density increase over the baseline appears to be a function of changes in age classes. Older age classes increase less relative to the baseline, but the increases are still substantial relative to 1985 (fig. 10b). Concomitantly, there is an increase in the younger age classes which, as described above, can provide grassy open areas for nesting and brood-rearing. The more equitable distribution between older and younger stands resulted in slightly greater densities of turkeys than observed under the baseline.

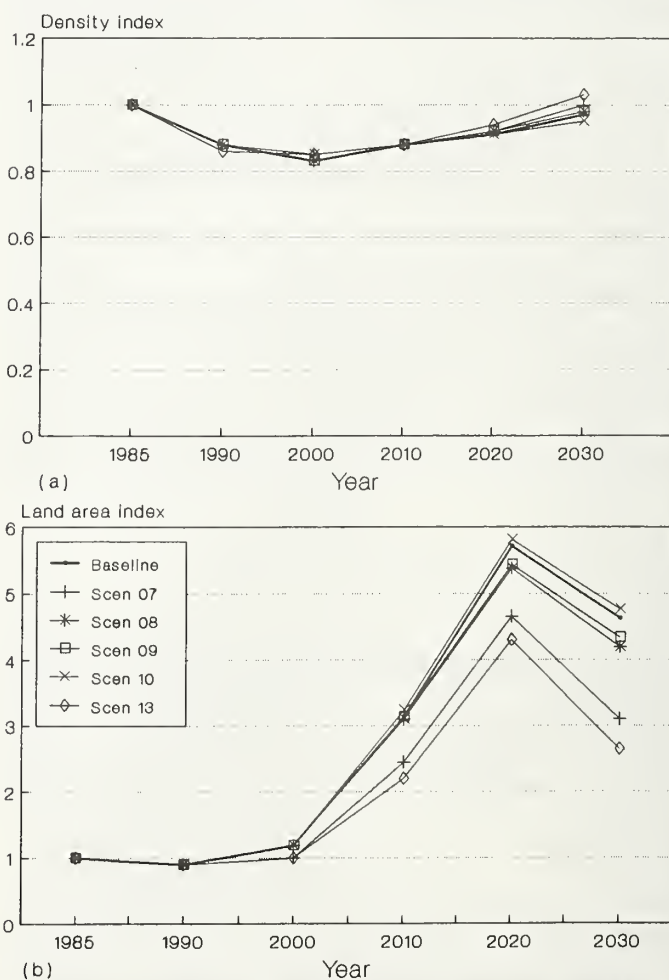


Figure 10.—Comparison of (a) indexed turkey response, and (b) indexed area change for hardwood age class 3 between the baseline and alternative land base scenarios in the South-central subregion.

## MANAGEMENT AND RESEARCH IMPLICATIONS

### Management Implications

The white-tailed deer and wild turkey models were designed to evaluate the possible effects of changing land use and timber management on a regional scale. The models represent empirical relationships between habitat (as represented by the proportion of land in various uses and timber cover at the county level) and observed deer and turkey density. Under a future of increased urbanization and more intensive timber management, white-tailed deer and wild turkey were projected to decline over a 50-year planning period. However, the models project what may occur if no wildlife management activities are directed at altering or mitigating the projected trends. Current management practices for deer and turkey, including harvest regulation and habitat management activities, are implicit in the model and assumed to remain constant over the planning period. For this reason, the baseline scenario does not necessarily reflect the future of the deer and turkey resource in the South; certainly, state and federal agencies have the option to intensify deer and turkey management to offset perceived declines. Similarly, private land owners may find increased economic incentive (access fees, hunter lease agreements) to manage their lands for wildlife production.

Because the observed changes in the land base across time are, in general, much greater than those among scenarios, projected deer and turkey density trends do not vary much from the baseline condition. For the application reported here, the projected baseline changes in deer and turkey densities are more critical in specifying potential management opportunities than the analysis of alternative scenarios. Over the projection period, the most notable change in timberland is the conversion of natural forest types to pine plantations. The majority of the increased acreage in planted pine will come from natural pine stands, although substantial acreages of mixed pine-hardwood and upland hardwoods also will be converted. The most important land use change will be the significant increase in human-related land uses—increasing by 66% over the planning period.

The projected increases in human-related land uses suggest that management consider activities to control for direct losses of habitat through urbanization and increased disturbance associated with increasing human populations. Management activities that control deer and turkey harvest, accessibility of lands to human use, and incentive programs to private land owners can help maintain deer and turkey populations into the future.

Similarly, implementation of region-wide forest management practices to mitigate the impacts associated with intensive management for softwood production could improve future deer and turkey populations. Controlling the spacing within pine plantings, maintaining hard and soft mast-producing plant species, and specifying the size, shape, and distribution of clearcuts will all help mitigate deer and turkey declines.

Intensification of forest management activities must also consider the likely increased costs to manage wild-

life. Funding through federal programs may help compensate for increased wildlife management costs. However, given the potential for declining deer and turkey populations and the crowding of hunters on a shrinking habitat base, one must consider the possibility of declining revenues from license sales and matching Pittman-Robertson funds. Human populations are expected to expand and land use is expected to intensify across the South. Unless the trends reviewed here change, state wildlife managing agencies could be faced with the challenge of solving increasingly complex management problems with a diminished financial base.

The deer and turkey models reviewed here do not address site-specific management recommendations. The models were developed to analyze potential impacts from broad land management activities, such as land use conversions, timber type conversions, or increased harvest of certain forest age classes. As such, the models provide a point of reference for evaluating and recommending future region-wide management activities.

### Research Opportunities

The purpose for developing regional deer and turkey models was to provide results from which planners and policy makers could evaluate the potential impacts from changes in land use and timber management activities. The wildlife models, in conjunction with the other resources specified in the multiresource framework, represent an initial effort to quantitatively incorporate wildlife into a joint analysis of natural resource management over a large geographic region. The analysis discussed here represents a first-generation effort and many simplifying assumptions where necessary. Now that a conceptual framework has been specified and applied, there is a basis for recommending future research activities that will permit explicit incorporation of the assumptions made in this analysis.

One of the most important and difficult future research opportunities is the incorporation of resource feedbacks. The current multiresource framework only addresses the impacts of land use and timber management on wildlife; other resource interactions are not considered. Modification of the timber growth and yield functions based on changes in wildlife populations or wildlife management would initiate an evolution toward a truly interactive analysis and improve the capability to represent the complexity of multiple resource systems.

From the standpoint of wildlife habitat relationships, there is a need to incorporate the effect of size, shape, and distribution of land types on wildlife populations. Theory and empirical evidence have shown that the size and juxtaposition of different land units is important in explaining variation in the distribution and abundance of wildlife species. Incorporating such features, however, will require land base inventories and models that measure and project landscape patterns at the regional level.

There is also a need to more rigorously validate and verify current models. Validation, or the testing of the

model on independent data, is particularly difficult given the scale of the analysis and the fact that wildlife projections represent future conditions. Although historical data may provide an opportunity for validation, data on wildlife populations and land base characteristics over a sufficiently large geographic area are rare and usually not temporally congruent. These characteristics limit the current capability to validate the models reported here and force reliance on model verification to evaluate model performance.

Verification is the process of determining if the models produce reasonable results. Included in model verification is the sensitivity of model output to input uncertainty. There are two sources of input uncertainty within the modeling framework used here: (1) in the inventory data used to generate the population-habitat relationships, and (2) in the output from the land area and timber inventory models that provided input to the wildlife models during the projection process. When the estimated classification accuracies are considered in conjunction with the relatively low sensitivity to land base changes across alternative scenarios, the question arises: What constitutes a significant change in predicted regional densities? Analysis of uncertainty in inventory data and how uncertainty is propagated through a network of resource models are areas of future research that will provide insights into precision of model predictions.

## CONCLUSIONS

Since the turn of the century, white-tailed deer and wild turkey populations have recovered dramatically from historic lows caused by exploitation and habitat degradation. In the South, current population estimates for deer and turkey are 29 and 47 times the nationwide population estimates for the early 1900's. Although intensive wildlife management for these species through protection and restocking programs contributed to the recovery, land use changes during this period provided the necessary habitat. Over the last 20 years, populations have continued to increase. Much of the increase in recent years appears to be occurring on private lands; deer and turkey population trends on public lands have leveled off. As in the past, future trends will depend, in part, on how lands in the South are used. Although alternative timber projections do not suggest large acreages will become deforested, more subtle but significant timber type conversions are projected. These large-scale timber type changes, together with increased urbanization, could significantly affect deer and turkey population levels.

Habitat-based population models were developed for deer and turkey in order to evaluate the potential impacts from projected changes in land use and timber management. Discriminant function relationships for six physiographic strata established empirical relationships between deer and turkey density classes and land base descriptors at the county level. Projections of increased urbanization and more intensive timber management for softwood production would likely lead to South-wide declines in deer and turkey densities.

Analysis of alternative land base descriptions showed similar trends in deer and turkey densities. The alternatives were designed to evaluate changes related to the timber resource not the wildlife resource. Consequently, deer and turkey population changes over time under the baseline condition were more valuable in evaluating future forest management policies.

The implications of the projected wildlife trends are logical. More intensive land use from human development or timber production will require more intensive wildlife management. Wildlife management practices that can ameliorate the effects of converting natural forest types to pine plantations could mitigate the projected declines. Similarly, wildlife harvest regulations, or controlling accessibility, could help offset the impacts associated with increasing human populations. In addition, economic incentives that promote favorable deer and turkey habitat on private lands could improve the trends reported here. Consequently, the deer and turkey declines are not what necessarily will occur but what may occur if consideration for these species is not included in managing the South's renewable resources.

The regional wildlife analysis presented here improves our capability to assess wildlife resources over large geographic areas. As part of a multiple resource modeling framework, impacts from changing land use and timber management can be examined simultaneously among other resources. Although several simplifying assumptions were made in the analysis, the feasibility of developing a regional analysis system from existing land base inventories was demonstrated. A conceptual framework and successful application provide a basis for recommending and incorporating wildlife interactions to achieve a more complete analysis of multiple resource questions.

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## APPENDIX A

White-tailed deer discriminant function analysis by stratum: (a) mean (standard error) transformed value of each predictor variable for each deer density class, and (b) classification summary table depicting the number (percent) of counties observed in each density class (rows) and model-predicted density class membership (columns).

### STRATUM: Mountain

a.	Variable	Low		Deer density class Moderate		High	
		Mean	(SE)	Mean	(SE)	Mean	(SE)
	TOTCRP	0.178	(0.010)	0.198	(0.021)	0.256	(0.024)
	HUMAN	0.275	(0.012)	0.266	(0.011)	0.264	(0.015)
	UH	0.733	(0.025)	0.731	(0.027)	0.649	(0.032)
	AGE1	0.369	(0.019)	0.291	(0.030)	0.327	(0.041)
	AGE2	0.583	(0.015)	0.483	(0.020)	0.560	(0.018)
	AGE3	0.394	(0.027)	0.544	(0.039)	0.420	(0.043)
b.							
	From class	Low		To class moderate		High	
	Low	54 (87)		5 (8)		3 (5)	
	Moderate	8 (23)		25 (71)		2 (6)	
	High	5 (26)		2 (11)		12 (63)	

Reclassification accuracy: 79%

### STRATUM: Piedmont

a.	Variable	Low		Deer density class Moderate		High	
		Mean	(SE)	Mean	(SE)	Mean	(SE)
	TOTCRP	0.308	(0.021)	0.267	(0.014)	0.357	(0.038)
	HUMAN	0.386	(0.026)	0.291	(0.011)	0.240	(0.012)
	UH	0.551	(0.018)	0.523	(0.013)	0.487	(0.021)
	AGE1	0.353	(0.011)	0.430	(0.013)	0.442	(0.022)
	AGE2	0.537	(0.015)	0.587	(0.012)	0.602	(0.027)
	AGE3	0.369	(0.015)	0.317	(0.016)	0.337	(0.025)
b.							
	From class	Low		To class moderate		High	
	Low	30 (65)		12 (26)		4 (9)	
	Moderate	9 (10)		76 (85)		4 (4)	
	High	2 (10)		3 (14)		16 (76)	

Reclassification accuracy: 78%

### STRATUM: Eastern Coastal Plain

a.	Variable	Low		Deer density class Moderate		High	
		Mean	(SE)	Mean	(SE)	Mean	(SE)
	TOTCRP	0.455	(0.019)	0.489	(0.022)	0.455	(0.039)
	HUMAN	0.264	(0.011)	0.223	(0.009)	0.203	(0.012)
	UH	0.307	(0.011)	0.393	(0.016)	0.395	(0.032)
	AGE1	0.350	(0.006)	0.395	(0.011)	0.406	(0.018)
	AGE2	0.528	(0.009)	0.532	(0.012)	0.550	(0.029)
	AGE3	0.323	(0.010)	0.364	(0.013)	0.363	(0.029)
b.							
	From class	Low		To class moderate		High	
	Low	110 (83)		21 (16)		2 (2)	
	Moderate	18 (28)		41 (64)		5 (8)	
	High	0 (0)		4 (20)		16 (80)	

Reclassification accuracy: 77%

STRATUM: Mid-South Coastal Plain

a.	Variable	Low		Deer density class Moderate		High	
		Mean	(SE)	Mean	(SE)	Mean	(SE)
	TOTCRP	0.488	(0.029)	0.335	(0.018)	0.354	(0.027)
	HUMAN	0.239	(0.008)	0.223	(0.008)	0.182	(0.008)
	UH	0.498	(0.030)	0.413	(0.016)	0.403	(0.016)
	AGE1	0.510	(0.015)	0.632	(0.015)	0.584	(0.016)
	AGE2	0.477	(0.024)	0.479	(0.019)	0.547	(0.013)
	AGE3	0.136	(0.023)	0.129	(0.013)	0.165	(0.016)

b.	From class	Low		To class moderate		High	
	Low	18	(78)	4	(17)	1	(4)
	Moderate	3	(5)	47	(85)	5	(9)
	High	0	(0)	4	(15)	22	(85)

Reclassification accuracy: 84%

STRATUM: Mississippi Valley

a.	Variable	Low		Deer density class Moderate		High	
		Mean	(SE)	Mean	(SE)	Mean	(SE)
	TOTCRP	0.834	(0.054)	0.861	(0.048)	0.578	(0.044)
	HUMAN	0.233	(0.016)	0.217	(0.009)	0.203	(0.013)
	UH	0.178	(0.032)	0.156	(0.033)	0.304	(0.036)
	AGE1	0.305	(0.026)	0.346	(0.022)	0.513	(0.021)
	AGE2	0.325	(0.032)	0.349	(0.022)	0.467	(0.022)
	AGE3	0.107	(0.025)	0.075	(0.020)	0.139	(0.020)

b.	From class	Low		To class moderate		High	
	Low	16	(57)	9	(32)	3	(11)
	Moderate	4	(14)	22	(76)	3	(10)
	High	1	(3)	5	(14)	29	(83)

Reclassification accuracy: 73%

STRATUM: Western Coastal Plain & Highlands

a.	Variable	Low		Deer density class Moderate		High	
		Mean	(SE)	Mean	(SE)	Mean	(SE)
	TOTCRP	0.233	(0.034)	0.181	(0.025)	0.133	(0.030)
	HUMAN	0.205	(0.013)	0.208	(0.011)	0.189	(0.005)
	UH	0.430	(0.030)	0.532	(0.026)	0.425	(0.027)
	AGE1	0.569	(0.023)	0.495	(0.015)	0.640	(0.022)
	AGE2	0.468	(0.030)	0.543	(0.020)	0.598	(0.029)
	AGE3	0.110	(0.022)	0.182	(0.018)	0.175	(0.022)

b.	From class	Low		To class moderate		High	
	Low	18	(86)	2	(10)	1	(5)
	Moderate	7	(16)	35	(78)	3	(7)
	High	0	(0)	0	(0)	21	(100)

Reclassification accuracy: 85%

## APPENDIX B

Wild turkey discriminant function analysis by stratum: (a) mean (standard error) transformed value of each predictor variable for each turkey density class, and (b) classification summary table depicting the number (percent) of counties observed in each density class (rows) and model-predicted density class membership (columns).

### STRATUM: Mountain

a.	Variable	Turkey density class					
		Low		Moderate		High	
		Mean	(SE)	Mean	(SE)	Mean	(SE)
	TOTCRP	0.192	(0.009)	0.237	(0.023)	0.099	(0.032)
	HUMAN	0.277	(0.010)	0.273	(0.015)	0.201	(0.021)
	UH	0.721	(0.021)	0.676	(0.027)	0.847	(0.050)
	AGE1	0.344	(0.018)	0.359	(0.034)	0.221	(0.032)
	AGE2	0.578	(0.014)	0.492	(0.020)	0.503	(0.035)
	AGE3	0.406	(0.024)	0.461	(0.042)	0.704	(0.043)
b.							
	From class	Low		To class moderate		High	
	Low	73 (96)		3 (4)		0 (0)	
	Moderate	11 (35)		19 (61)		1 (3)	
	High	0 (0)		0 (0)		9 (100)	

Reclassification accuracy: 87%

### STRATUM: Piedmont

a.	Variable	Turkey density class					
		Low		Moderate		High	
		Mean	(SE)	Mean	(SE)	Mean	(SE)
	TOTCRP	0.327	(0.016)	0.284	(0.020)	0.226	(0.018)
	HUMAN	0.370	(0.015)	0.260	(0.012)	0.217	(0.009)
	UH	0.502	(0.010)	0.562	(0.016)	0.547	(0.027)
	AGE1	0.375	(0.009)	0.441	(0.018)	0.471	(0.023)
	AGE2	0.554	(0.012)	0.569	(0.017)	0.631	(0.018)
	AGE3	0.333	(0.013)	0.321	(0.023)	0.325	(0.026)
b.							
	From class	Low		To class moderate		High	
	Low	75 (84)		9 (10)		5 (6)	
	Moderate	11 (27)		25 (61)		5 (12)	
	High	6 (18)		1 (3)		27 (79)	

Reclassification accuracy: 78%

### STRATUM: Eastern Coastal Plain

a.	Variable	Turkey density class					
		Low		Moderate		High	
		Mean	(SE)	Mean	(SE)	Mean	(SE)
	TOTCRP	0.521	(0.015)	0.336	(0.029)	0.299	(0.043)
	HUMAN	0.253	(0.009)	0.232	(0.017)	0.224	(0.018)
	UH	0.321	(0.010)	0.376	(0.022)	0.418	(0.038)
	AGE1	0.362	(0.006)	0.388	(0.012)	0.382	(0.022)
	AGE2	0.519	(0.008)	0.547	(0.014)	0.594	(0.021)
	AGE3	0.326	(0.009)	0.363	(0.017)	0.387	(0.019)
b.							
	From class	Low		To class moderate		High	
	Low	145 (93)		7 (4)		4 (3)	
	Moderate	13 (33)		26 (65)		1 (3)	
	High	4 (19)		1 (5)		16 (76)	

Reclassification accuracy: 86%

STRATUM: Mid-South Coastal Plain

a.	Variable	Low		Turkey density class Moderate		High	
		Mean	(SE)	Mean	(SE)	Mean	(SE)
	TOTCRP	0.450	(0.028)	0.378	(0.021)	0.313	(0.024)
	HUMAN	0.237	(0.008)	0.230	(0.009)	0.181	(0.007)
	UH	0.507	(0.032)	0.397	(0.017)	0.423	(0.014)
	AGE1	0.547	(0.024)	0.593	(0.015)	0.626	(0.018)
	AGE2	0.473	(0.025)	0.485	(0.018)	0.528	(0.020)
	AGE3	0.104	(0.024)	0.142	(0.015)	0.162	(0.012)
b.							
	From class	Low		To class moderate		High	
	Low	17 (74)		2 (9)		4 (17)	
	Moderate	5 (10)		37 (76)		7 (14)	
	High	1 (3)		7 (22)		24 (75)	

Reclassification accuracy: 75%

STRATUM: Mississippi Valley

a.	Variable	Low		Turkey density class Moderate		High	
		Mean	(SE)	Mean	(SE)	Mean	(SE)
	TOTCRP	0.799	(0.036)	0.810	(0.055)	0.551	(0.076)
	HUMAN	0.219	(0.007)	0.223	(0.020)	0.204	(0.020)
	UH	0.185	(0.026)	0.244	(0.045)	0.267	(0.048)
	AGE1	0.341	(0.022)	0.409	(0.029)	0.509	(0.029)
	AGE2	0.386	(0.021)	0.324	(0.031)	0.458	(0.033)
	AGE3	0.126	(0.018)	0.054	(0.019)	0.134	(0.029)
b.							
	From class	Low		To class moderate		High	
	Low	40 (85)		5 (11)		2 (4)	
	Moderate	5 (21)		18 (75)		1 (4)	
	High	3 (14)		3 (14)		15 (71)	

Reclassification accuracy: 79%

STRATUM: Western Coastal Plain & Highlands

a.	Variable	Low		Turkey density class Moderate		High	
		Mean	(SE)	Mean	(SE)	Mean	(SE)
	TOTCRP	0.214	(0.028)	0.199	(0.036)	0.101	(0.026)
	HUMAN	0.212	(0.009)	0.210	(0.017)	0.192	(0.020)
	UH	0.432	(0.022)	0.590	(0.050)	0.434	(0.023)
	AGE1	0.565	(0.019)	0.514	(0.028)	0.539	(0.022)
	AGE2	0.542	(0.020)	0.594	(0.024)	0.621	(0.028)
	AGE3	0.155	(0.015)	0.205	(0.028)	0.267	(0.016)
b.							
	From class	Low		To class moderate		High	
	Low	38 (90)		2 (5)		2 (5)	
	Moderate	8 (44)		10 (56)		0 (0)	
	High	1 (8)		0 (0)		12 (9)	

Reclassification accuracy: 82%

## APPENDIX C

### DESCRIPTION OF ALTERNATIVE SCENARIOS

1. Wharton growth assumptions with cycles. The future as described by the basic assumptions and other specified and implied assumptions in this report, modified by substituting the assumptions on population, gross national product, per-capita disposable income, housing, and other demand determinants, including economic cycles, contained in "Long-term Alternative Scenarios and 20-year Extension," Wharton Econometric Forecasting Associates, Vol. 3., No. 1, February 1985, for those contained in this study through 2005. For years after 2005, the assumptions used in this report were adjusted to be consistent with the Wharton 20-year trends and levels.

2. Improved processing efficiency. The future as described by the basic assumptions and other specified and implied assumptions in this report, modified by increasing lumber and plywood yields 15 percentage points above the 10% increase assumed in the base projections. The increase in yields will be staged in the progression 9%, 7%, 5%, 3%, and 1% per decade.

3. Fifteen percent softwood lumber tariffs. The future as described by the basic assumptions and other specified and implied assumptions in this report, modified by the imposition of a 15% ad valorem duty on softwood lumber imports effective in 1986.

4. High exports of timber products. The future as described by the basic assumptions and other specified and implied assumptions in this report, modified by increasing the projected exports of lumber, plywood, and pulpwood (including pulpwood and the pulpwood equivalent of pulp, paper, and board) by 20% in 1990, 40% in 2000, 60% in 2010, 80% in 2020, and 100% in 2030.

5. High imports of timber products. The future as described by the basic assumptions and other specified and implied assumptions in this report, modified by increasing the projected imports of plywood, pulpwood (including pulpwood and the pulpwood equivalent of pulp, paper, and board), and hardwood lumber and logs by 20% in 1990, 40% in 2000, 60% in 2010, 80% in 2020, and 100% in 2030.

6. Reduced U.S./Canadian exchange rate. The future as described by the basic assumptions and other specified and implied assumptions in this report, modified by reducing the U.S. exchange rate with Canada—U.S. dollars per Canadian dollar—to 0.80 in 1990, 0.85 in 2000, and 0.90 in 2030. In the basic assumptions, the exchange rate was assumed to be 0.86 in 1990, 0.95 in 2000 and 0.98 in 2030.

7. Increased stumpage costs. The future as described by the basic assumptions and other specified and implied assumptions in this report, modified by increasing stumpage prices above the base projections by 5% by 1990, 10% by 2000, 15% by 2010, and 20% by 2020.

8. Reduced timberland area. The future as described by the basic assumptions and other specified and implied assumptions in this report, modified by reducing the projected area in timberland in the South by 2 million acres in 1990, 5 million acres in 2000, and 11 million acres in 2030.

9. Reduced timber growth. The future as described by the basic assumptions and other specified and implied assumptions in this report, modified by reducing by 25% to net annual growth on pine plantations, natural pine, and mixed pine-hardwood stands shown in the empirical yield tables used in developing the base-level projections.

10. Reduced National Forest System harvest. The future as described by the basic and other specified and implied assumptions in this report, modified by reducing timber harvests on the national forests to 8.1 billion board feet in 1990 and maintaining this level through 2030.

11. Natural regeneration on cropland and pastureland. The future as described by the basic assumptions and other specified and implied assumptions in this report, modified by assuming that all the cropland and pastureland in the South that would yield higher rates of return in pine plantations would naturally revert to timberland by 2000 (70% natural pine, 30% hardwoods in the Southeast; 40% natural pine, 60% hardwoods in the South-central).

12. Economic opportunities on cropland and pastureland. The future as described by the basic assumptions and other specified and implied assumptions in this report, modified by assuming that all the economic opportunities (those that would yield 4% or more net of inflation or deflation) for establishing pine plantations on marginal cropland and pastureland would be utilized.

13. Economic opportunities on private timberlands. The future as described by the basic assumptions and other specified and implied assumptions in this report, modified by assuming that all the economic opportunities for increasing timber supplies on timberland in private ownerships that yield 4% or more net of inflation or deflation would be utilized.

14. Increased management intensity on forest industry timberlands in the Douglas-fir region. The future as described by the basic assumptions and other specified and implied assumptions in this report, modified by assuming that all the economic opportunities to increase timber supplies on forest industry timberlands in the Douglas-fir region would be utilized.

# APPENDIX D

White-tailed deer and wild turkey density (number per square mile) responses to baseline and alternative scenarios.

## White-tailed deer

	BASE	SCEN 07	SCEN 08	SCEN 09	SCEN 10	SCEN 13
Southeast						
1985	17.0	17.0	17.0	17.0	17.0	17.0
1990	16.9	16.9	17.0	16.9	16.9	16.8
2000	16.6	16.5	16.9	16.4	16.6	16.6
2010	15.8	15.7	16.4	15.8	15.8	15.5
2020	15.1	14.8	15.7	15.1	15.1	14.8
2030	14.5	14.3	15.2	14.5	14.4	14.3
South-central						
1985	17.6	17.6	17.6	17.6	17.6	17.6
1990	16.9	16.9	16.9	16.9	16.9	16.8
2000	16.5	16.6	16.6	16.5	16.6	16.7
2010	16.0	16.2	16.1	15.9	16.0	16.4
2020	14.3	14.9	14.3	14.3	14.2	15.0
2030	13.6	14.4	13.3	13.7	13.5	14.4

## Wild turkey

	BASE	SCEN 07	SCEN 08	SCEN 09	SCEN 10	SCEN 13
Southeast						
1985	5.3	5.3	5.3	5.3	5.3	5.3
1990	5.2	5.1	5.1	5.1	5.1	5.2
2000	4.9	4.9	4.8	4.9	4.9	5.0
2010	4.7	4.7	4.5	4.6	4.6	4.7
2020	4.7	4.8	4.5	4.7	4.7	4.8
2030	4.8	4.9	4.6	4.9	4.8	5.0
South-central						
	BASE	SCEN 07	SCEN 08	SCEN 09	SCEN 10	SCEN 13
1985	6.6	6.6	6.6	6.6	6.6	6.6
1990	5.8	5.8	5.8	5.8	5.8	5.7
2000	5.5	5.5	5.6	5.5	5.5	5.6
2010	5.8	5.8	5.8	5.8	5.8	5.8
2020	6.0	6.1	6.1	6.1	6.0	6.2
2030	6.4	6.6	6.5	6.5	6.3	6.8

Flather, Curtis H.; Hoekstra, Thomas W.; Chalk, David E.; Cost, Noel D.; Rudis, Victor A. 1989. Recent historical and projected trends in white-tailed deer and wild turkey in the southern United States. Gen. Tech. Rep. RM-172. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 22 p.

An analysis of the historical and future status of white-tailed deer and wild turkey populations in the southern United States is presented. Habitat-based models that statistically relate deer and turkey densities to land use and forest cover at the county level are used to evaluate regional impacts from alternative timber management and land use projections.

**Keywords:** Regional model, multiple resource analysis, white-tailed deer, wild turkey, South, habitat model, statistical model



Rocky  
Mountains



Southwest



Great  
Plains

U.S. Department of Agriculture  
Forest Service

## Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

### RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

### RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico  
Flagstaff, Arizona  
Fort Collins, Colorado \*  
Laramie, Wyoming  
Lincoln, Nebraska  
Rapid City, South Dakota  
Tempe, Arizona

\*Station Headquarters: 240 W. Prospect Rd., Fort Collins, CO 80526